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TECHNICAL NOTE No. 1055

DECEMBER 1955

Comparison Of Aerodynamic Characteristics Of 20MM, HEI, T282EI Shell With Fuze M505 And 20MM, HEI, T282EI Shell With Fuze T321

EUGENE D. BOYER

DEPARTMENT OF THE ARMY PROJECT No. 5B03-07-002
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-0426 (AIR)

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EDBoyer/mjf
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ABSTRACT

Comparison of the aerodynamic characteristics of the 20mm HEI, T282E1 shell with a standard M505 fuze and with a T321 fuze showed no significant difference at velocities where the presence of the arming ball rotor in the M505 fuze does not influence the dynamics. Above M = 1.6, the T282E1 shell with the T321 fuze behaves the same as with the M505 fuze with the rotor removed.

TABLE OF SYMBOLS AND COEFFICIENTS

A	axial moment of inertia	(gram - in^2)
B	transverse moment of inertia	(gram - in^2)
d	diameter in inches	
K_D	Drag coefficient	
K_H	Damping moment coefficient	
K_N	Normal force coefficient	
K_T	Magnus moment coefficient	
K_M	Overturning moment coefficient	
CP_N	Normal force center of pressure	
M	Mach number	
N	Number of yaw stations	
N_T	Number of timing stations	
m	Weight in grams	
c.m.	Center of mass in calibers from base	
ℓ	Overall length in calibers	
$\lambda_{1,2}$	Yaw damping rates	
$\overline{\delta^2}$	Mean squared yaw (Degrees^2)	
$K_{D_{\delta^2}}$	Yaw drag coefficient	
K_{Do}	Zero yaw drag coefficient	
$K_{1,2}$	Magnitude of epicyclic yaw arms	
S_L	Swerve associated with the lift force	
s	Gyroscopic stability factor	
$\bar{s}$	Dynamic stability factor	
ϵ_y	Error in yaw fit	
ϵ_s	Error in swerve fit	

INTRODUCTION

Preparation of firing tables for a bullet fired from high speed aircraft and involving conditions of large yaws is a complicated matter. Therefore, it is very desirable, if possible, to spot check firing table entries by actual observations. This is difficult but could be done by accurately instrumented aircraft recording the initial conditions of the bullet's trajectory and exploding the bullet at a predetermined time so that both the aircraft and the explosion could be photographed from the ground. For the 20mm HEI, T282E1, shell this procedure required the development of a special time fuze. This has been done by the Bulova Watch Company and the fuze is designated as T321.

Our job was to compare the aerodynamic characteristics of the T282 shell with the T321 fuze relative to those of the same shell equipped with the standard M505 fuze. This note contains the results of such a comparison.

Ten rounds of shell with the T321 fuze were fired in the Aerodynamics Range at Mach numbers from 0.78 to 3.2. The characteristics of the T282E1 shell with M505 fuze are contained in Reference 1.

TREATMENT OF DATA

The aerodynamic coefficients are extracted from attitude, position, and time measurements of the shell by employing standard linearized reduction techniques[2]. Table I gives the physical measurements for the shell with both fuzes. Table II lists the aerodynamic data for each round with the T321 fuze. The aerodynamic data for the shell with the M505 fuze can be found in Tables II and III of Reference 1.

Figures 1 through 8 compare the aerodynamic coefficients of the shell with the T321 fuze, with the M505 fuze, and with the modified* M505 fuze. The solid line represents the M505 fuze; the broken line, the modified M505 fuze. Since the modified fuze differed from the M505 fuze only in K_H and λ_1, only Figures 6 and 7 have a broken line. The data for the T321 fuze are plotted as circled points.

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* The arming ball rotor was removed from the fuze.

RESULTS

As was expected, the aerodynamic coefficients, other than K_H, of the shell do not change significantly by substituting the T321 fuze for the M505 fuze. Consequently, the sole purpose of Figures 1 through 5 (which plot K_{Do}, K_M, K_N, CP_N, and K_T, respectively, vs. Mach number) is to depict the aerodynamic similarity of both fuzes. For Figure 1, K_D was reduced to K_{Do} by the equation: $K_D = K_{Do} + K_{D_{\delta^2}} \overline{\delta^2}$. For the comparison of K_M values in Figure 2, it was necessary to compute the moment with the T321 fuze about the c.m. position of the M505 fuzed shell.

Figure 6 shows the difference in observed K_H values between the two fuze types for varying Mach number. Above M = 1.6, K_H for the shell with the T321 fuze coincides with K_H with the modified M505 fuze, the unmodified M505 fuzed shell having smaller K_H values.

Figures 7 and 8 show λ_1 and λ_2, the yaw damping rates plotted vs. Mach number. The observed differences in K_H are naturally reflected in λ_1; these differences in K_H do not materially affect λ_2.

Plate 1 is a photograph of the shell with both fuze types. Plate 2 is a shadowgraph of the T321 fuzed shell in flight.

Eugene D. Boyer

EUGENE D. BOYER

TABLE I

Physical Measurements of 20mm, HEI, T282E1 Shell

	Units	With M505 Fuze	With T321 Fuze
m	grams	98.163	97.861
c.m.	calibers from base	1.566	1.536
A	gram - in^2	8.305	8.313
B	gram - in^2	62.56	59.43
ℓ	calibers	3.819	3.799
d	inches	.784	.784

TABLE II

AERODYNAMIC COEFFICIENTS

Rd No	M	$\overline{\delta^2}$	K_D	K_M	K_N	K_H	K_T	$\lambda_1 x10^3$	$\lambda_2 x10^3$	K_1	K_2	$\bar{s}$	s	N	N_T	ϵ_y	ϵ_s	S_L
3906*	.788	9.16	.0996							.003	.052				7			
3907**	.794	10.46	.0990	.991		-3.91	.43	-.91	-3.89	.014	.049	1.47	2.24	16	8	.0030		
3908	1.404	8.43	.2181	1.055	1.10	2.28	0	3.89	1.01	.033	.035	.54	2.25	26	7	.0014	.0076	.16
3909	1.460	2.94	.2078	1.046	1.10	2.02	-.01	3.25	1.30	.022	.017	.67	2.24	25	8	.0013	.0076	.08
3910	1.818	13.71	.1950	.962	1.13	2.56	-.05	3.47	1.87	.046	.042	.76	2.42	22	7	.0014	.0079	.24
3911	2.146	4.71	.1745	.899	1.16	2.35	-.03	3.36	1.67	.022	.029	.73	2.64	25	9	.0024	.0093	.21
3912	2.904	4.23	.1472	.744	1.11	1.91	-.06	2.24	2.09	.025	.024	.97	2.89	21	6	.0016	.0087	.23
3913	2.924	8.23	.1497	.770	1.11	1.80	-.04	2.28	1.83	.034	.034	.91	3.02	27	9	.0017	.0050	.34
3914	3.087	5.10	.1430	.762	1.08	1.84	-.06	2.08	2.13	.027	.026	1.01	3.02	26	8	.0012	.0069	.26
3915	3.257	3.31	.1379	.747	1.11	1.87	-.08	1.84	2.46	.022	.021	1.12	3.11	24	9	.0023	.0098	.23

* Nutational yaw arm too small for reduction.

** Since no satisfactory swerve reduction was obtained, K_H, K_T, and $\bar{s}$ were computed by using K_N from Reference 1.

REFERENCES

1. Boyer, E. D., Aerodynamic Characteristics for Small Yaws of 20mm Shell, HEI, T282E1 With Fuze M505 For Mach Numbers .36 to 3.78, BRLM Report No. 916 (1955) (CONFIDENTIAL).

2. Murphy, C. H., Data Reduction for the Free Flight Spark Ranges, BRL Report No. 900 (1954).

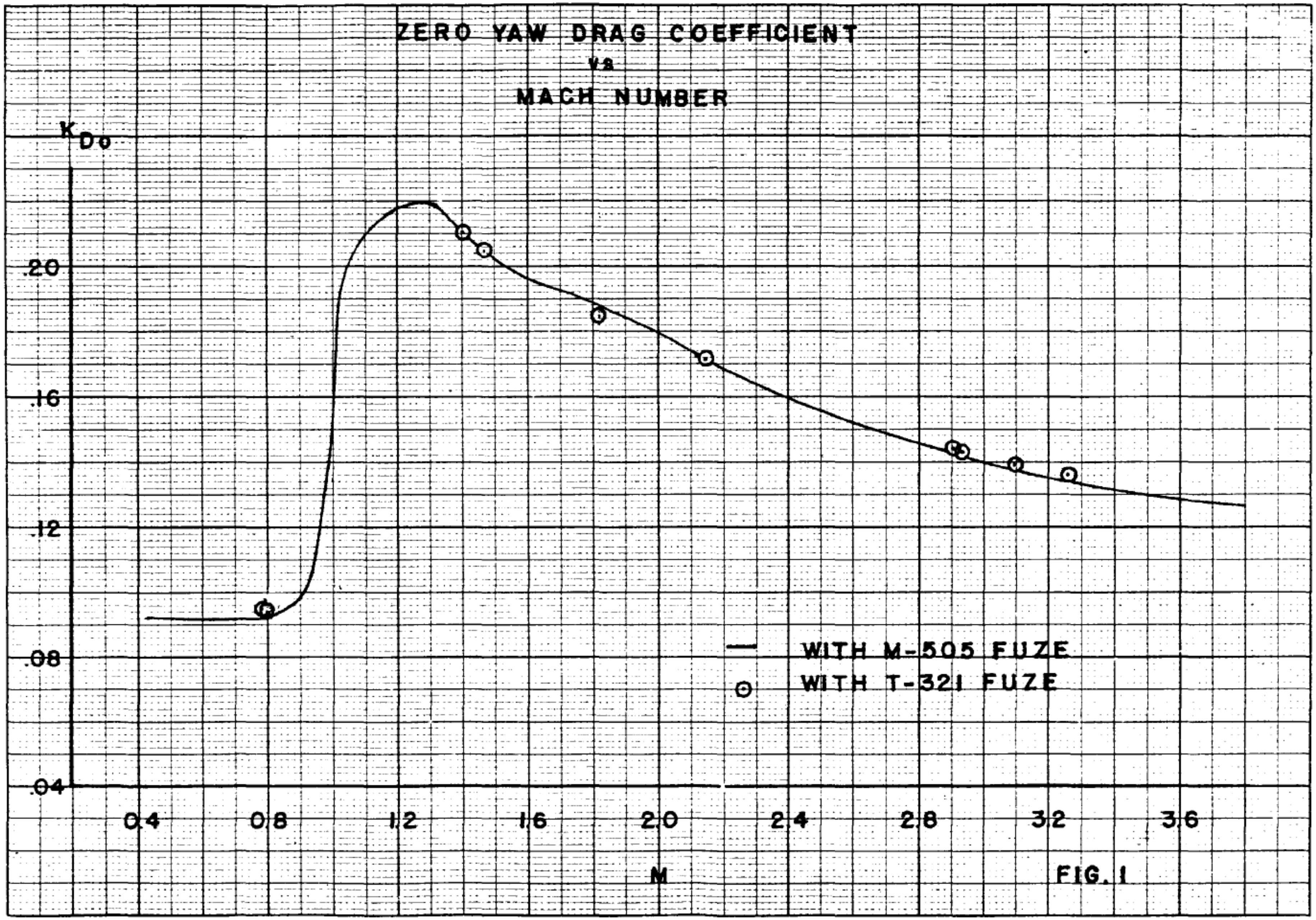
ZERO YAW DRAG COEFFICIENT
vs
MACH NUMBER
K_{D_0}
.20
.16
.12
.08
.04
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M
WITH M-505 FUZE
WITH T-321 FUZE

FIG. 1

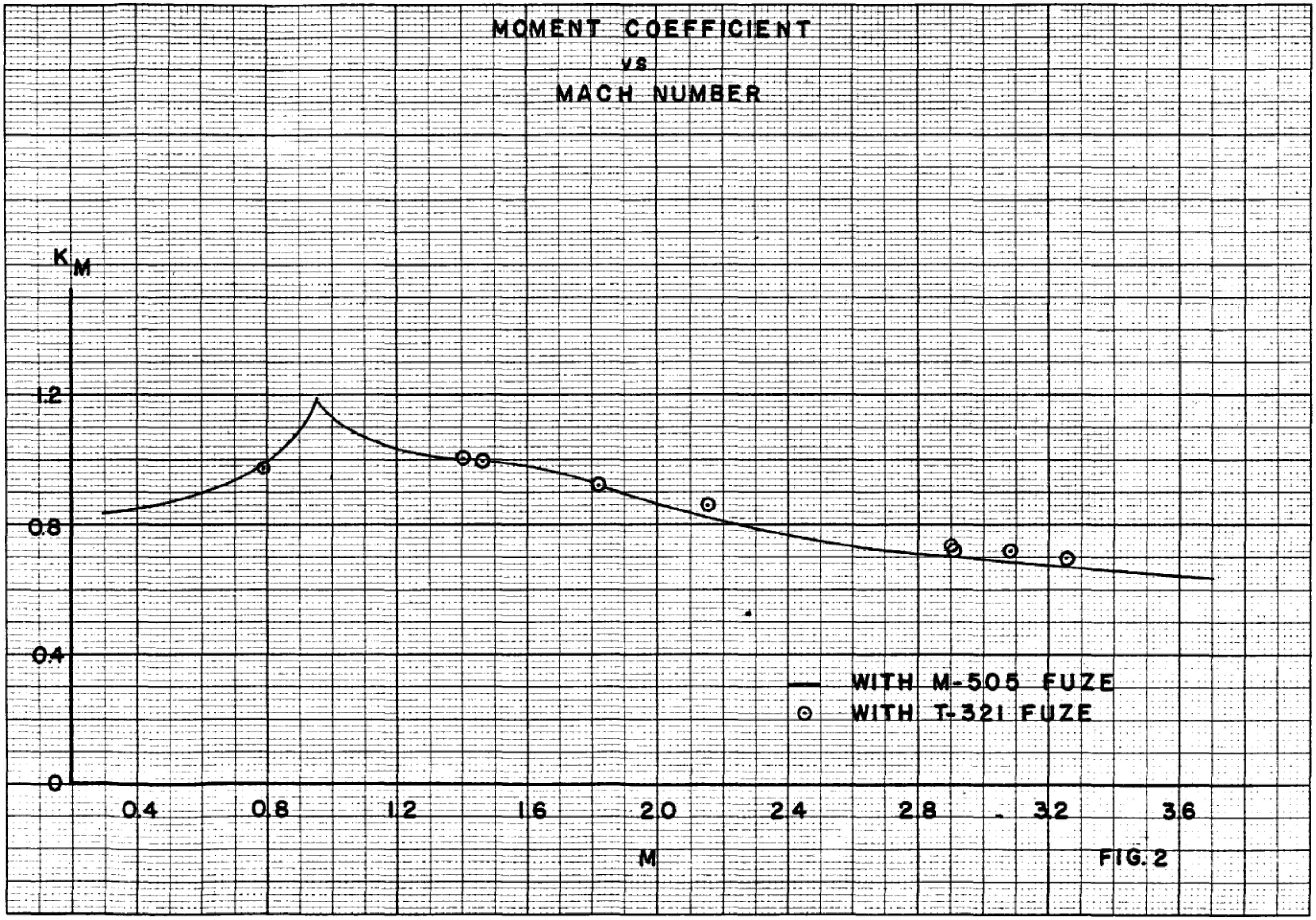
MOMENT COEFFICIENT
vs
MACH NUMBER
K_M
1.2
0.8
0.4
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M
WITH M-505 FUZE
WITH T-321 FUZE

FIG. 2

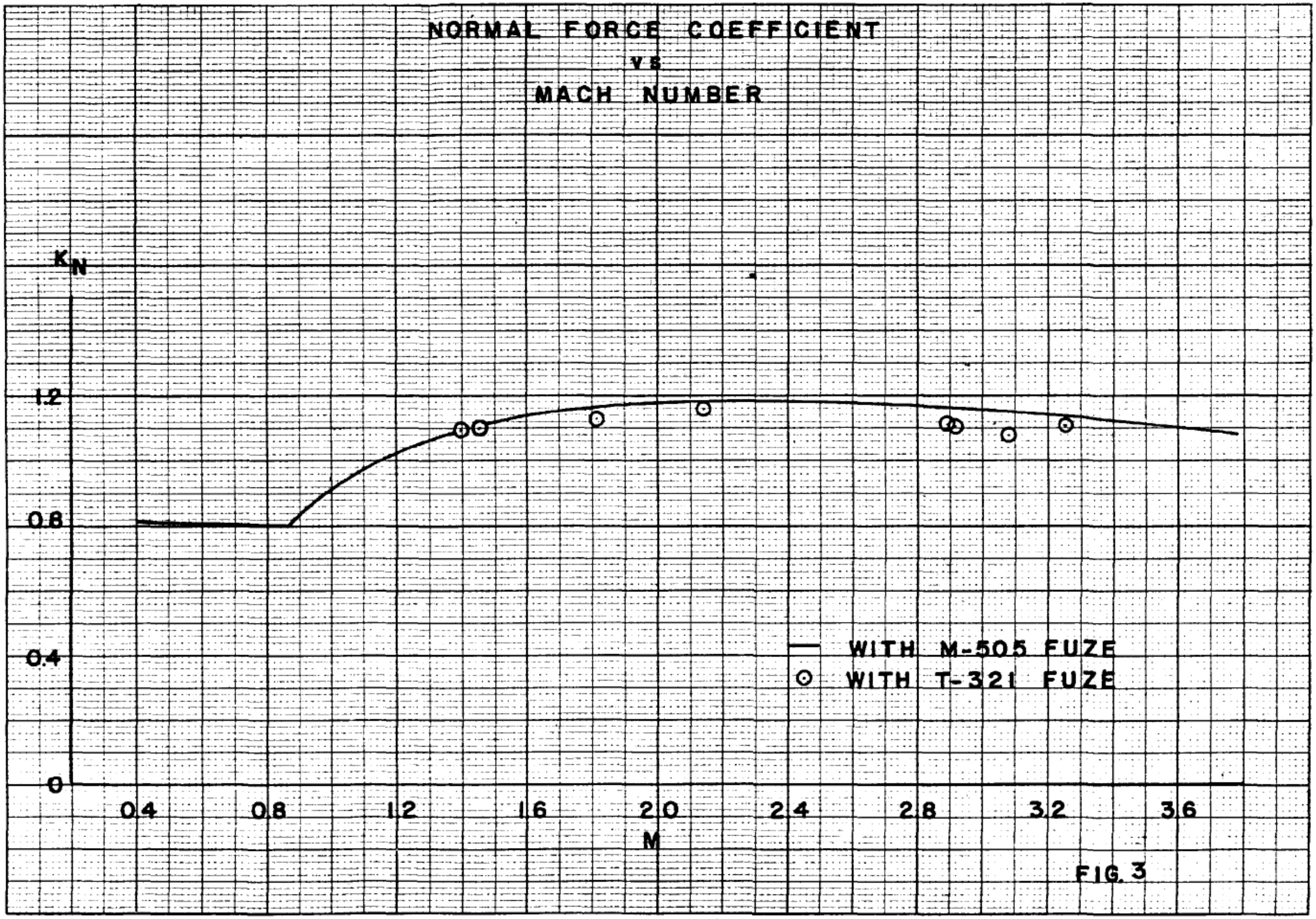
NORMAL FORCE COEFFICIENT
VS
MACH NUMBER
K_N
1.2
0.8
0.4
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M
WITH M-505 FUZE
WITH T-321 FUZE

FIG. 3

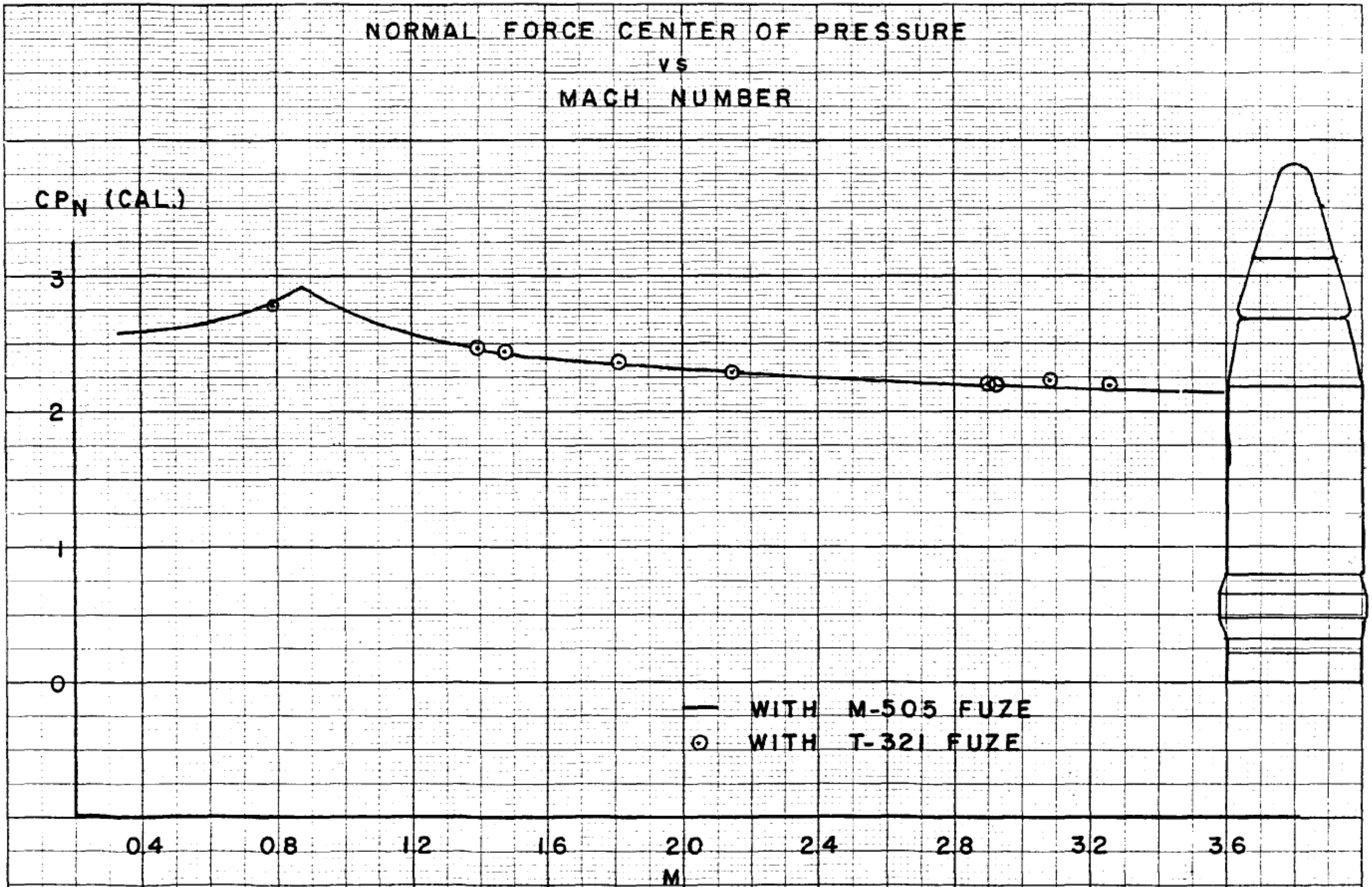
NORMAL FORCE CENTER OF PRESSURE
VS
MACH NUMBER
CPN (CAL.)
3
2
1
0
WITH M-505 FUZE
WITH T-321 FUZE
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M

FIG. 4

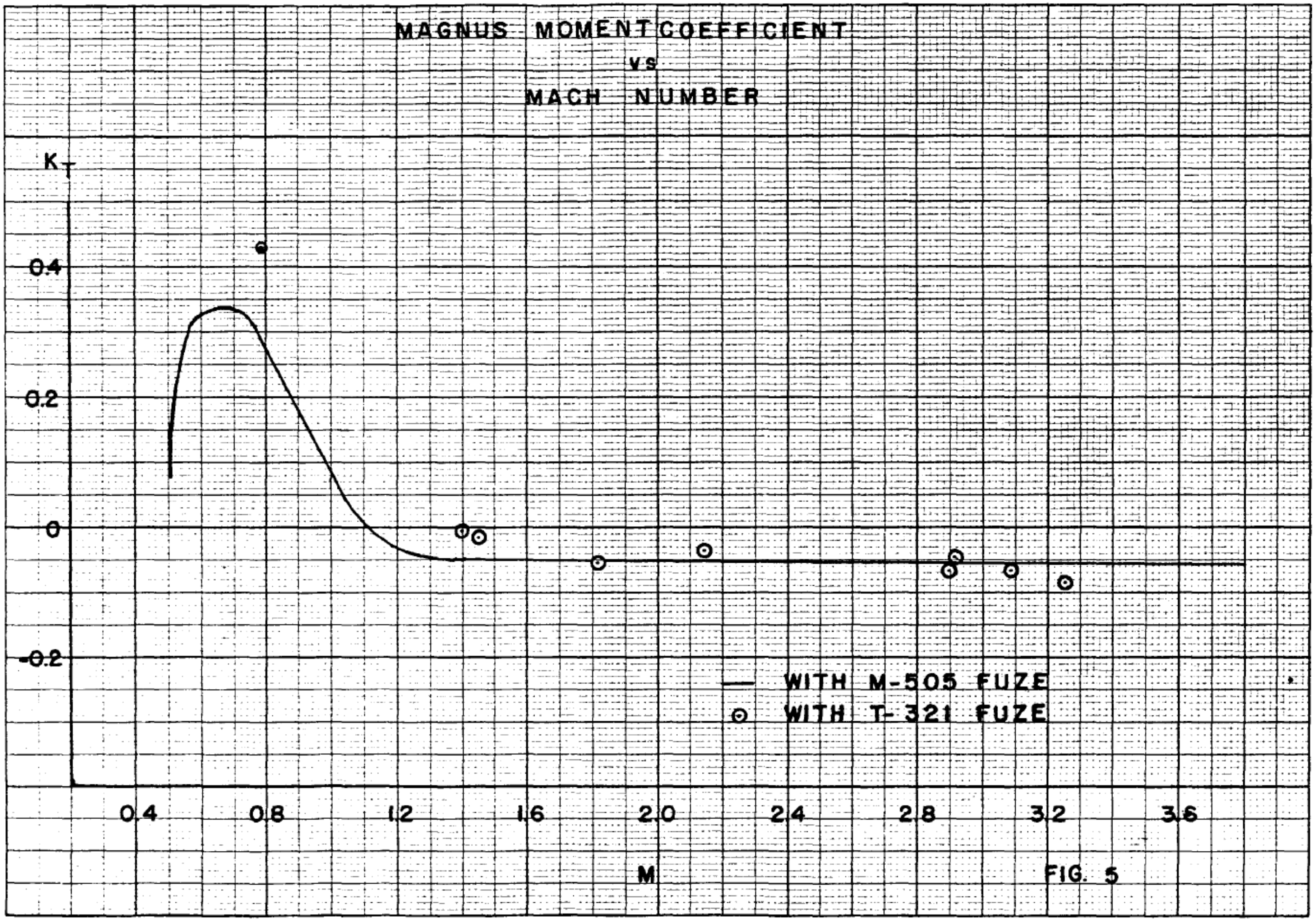
MAGNUS MOMENT COEFFICIENT
VS
MACH NUMBER
K_T
0.4
0.2
0
-0.2
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M
WITH M-505 FUZE
WITH T-321 FUZE

FIG. 5

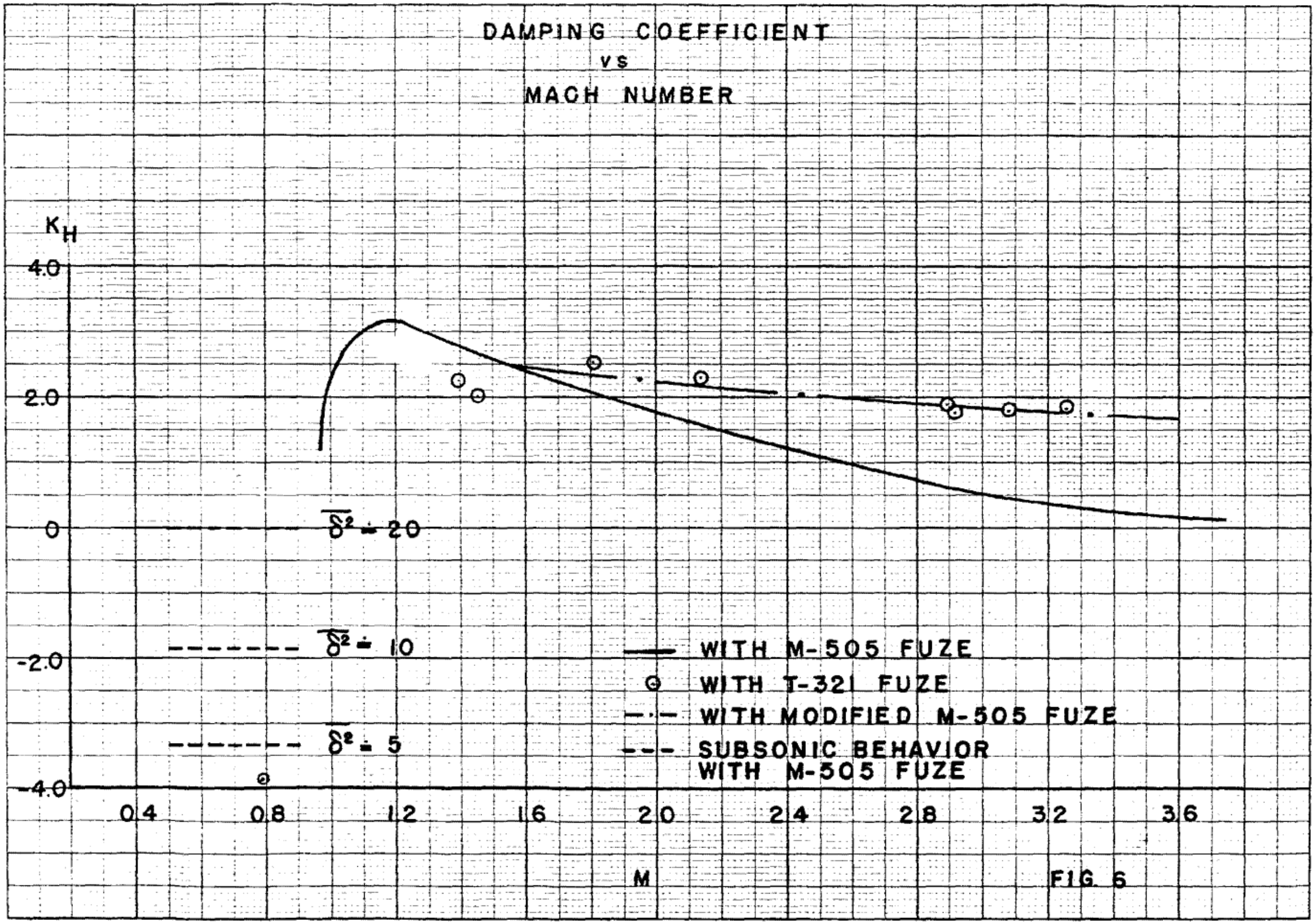
DAMPING COEFFICIENT
VS
MACH NUMBER
K_H
4.0
2.0
0
-2.0
-4.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M
$\overline{\delta^2} \doteq 20$
$\overline{\delta^2} \doteq 10$
$\overline{\delta^2} \doteq 5$
WITH M-505 FUZE
WITH T-321 FUZE
WITH MODIFIED M-505 FUZE
SUBSONIC BEHAVIOR
WITH M-505 FUZE

FIG. 6

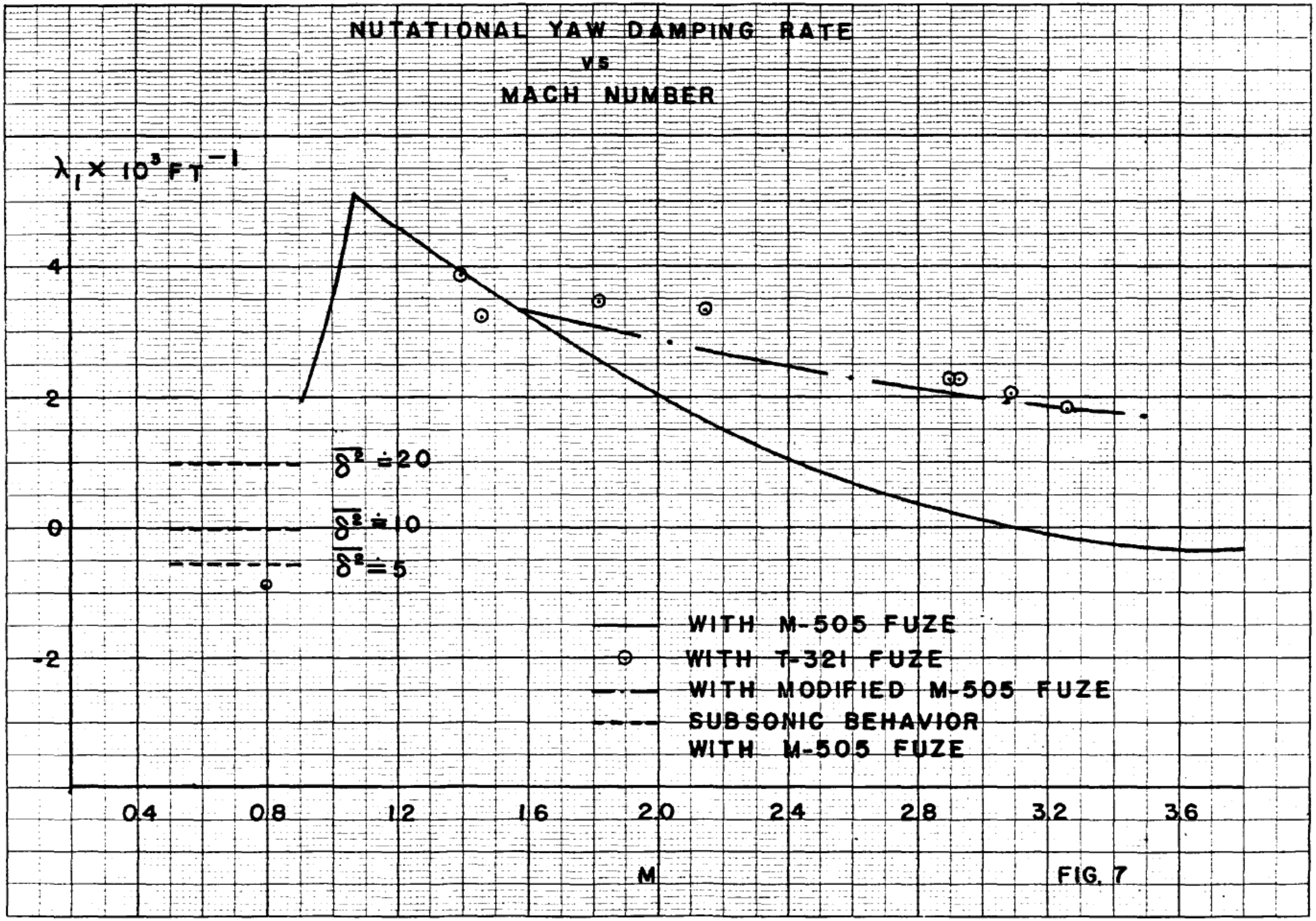
NUTATIONAL YAW DAMPING RATE
VS
MACH NUMBER
$\lambda_1 \times 10^3$ FT^{-1}
4
2
0
-2
$\overline{\delta^2} \doteq 20$
$\overline{\delta^2} \doteq 10$
$\overline{\delta^2} \doteq 5$
WITH M-505 FUZE
WITH T-321 FUZE
WITH MODIFIED M-505 FUZE
SUBSONIC BEHAVIOR
WITH M-505 FUZE
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M

FIG. 7

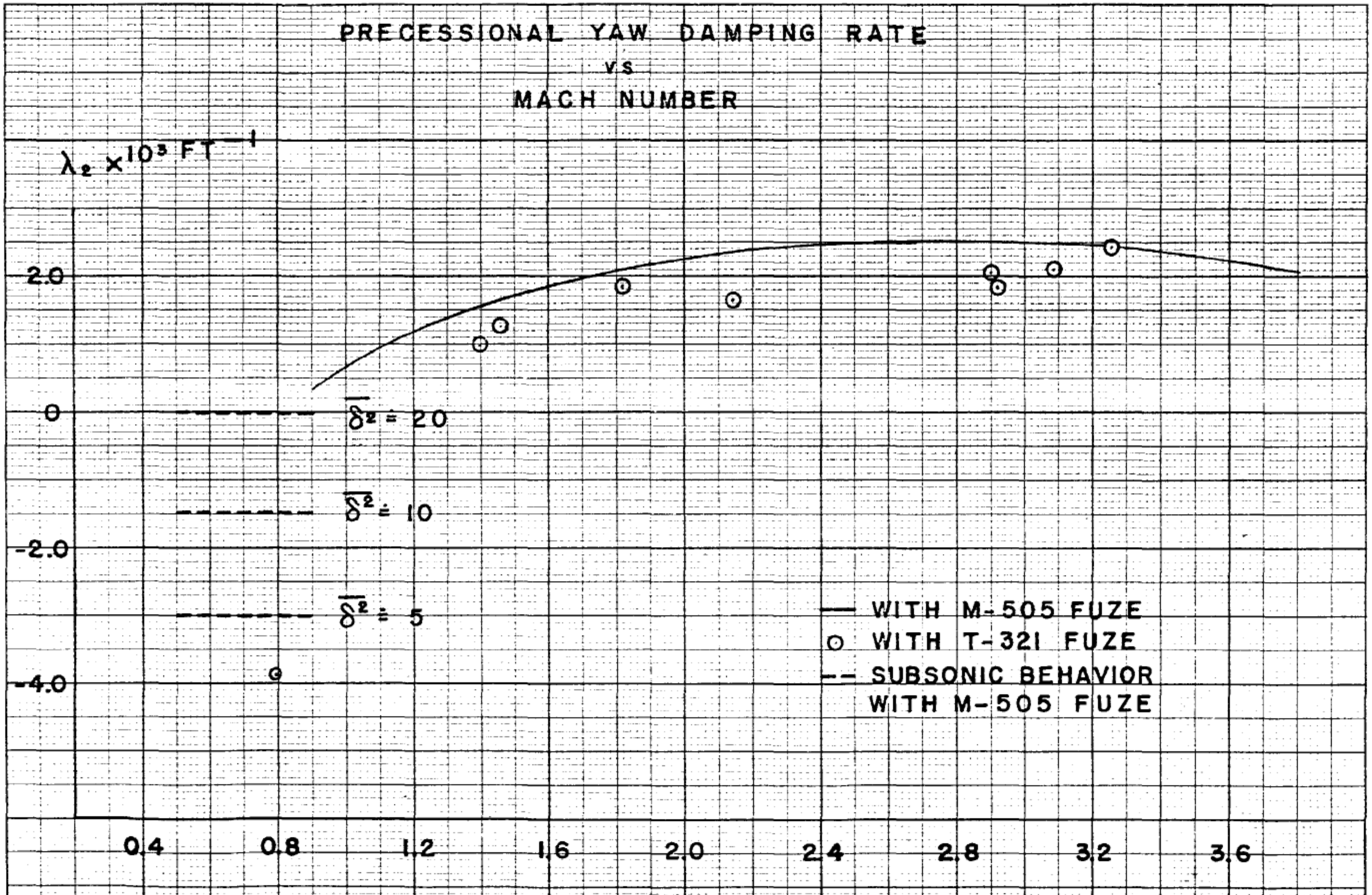
PRECESSIONAL YAW DAMPING RATE
vs
MACH NUMBER
$\lambda_2 \times 10^3$ FT^{-1}
2.0
0
-2.0
-4.0
$\overline{\delta^2} = 20$
$\overline{\delta^2} \doteq 10$
$\overline{\delta^2} \doteq 5$
WITH M-505 FUZE
WITH T-321 FUZE
SUBSONIC BEHAVIOR
WITH M-505 FUZE
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
M

FIG. 8

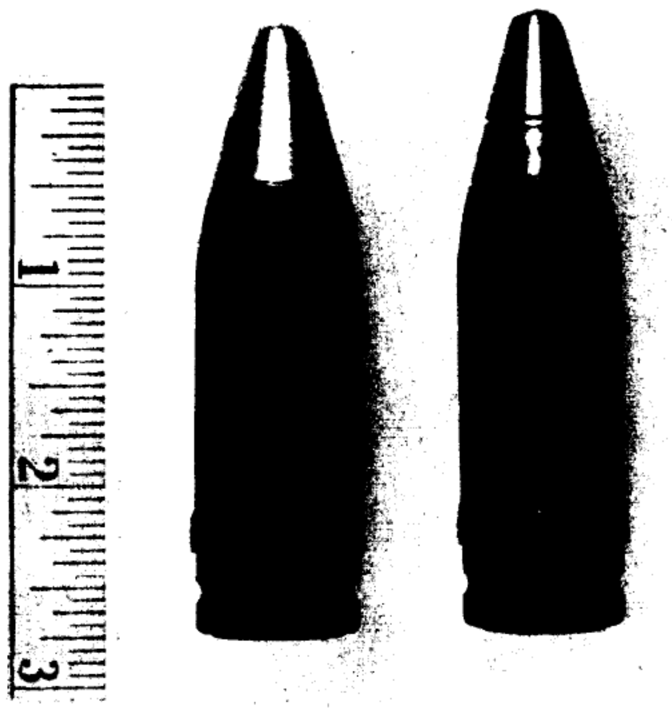

PLATE 1. Photograph of Shell
Left: M505 Fuze
Right: T321 Fuze

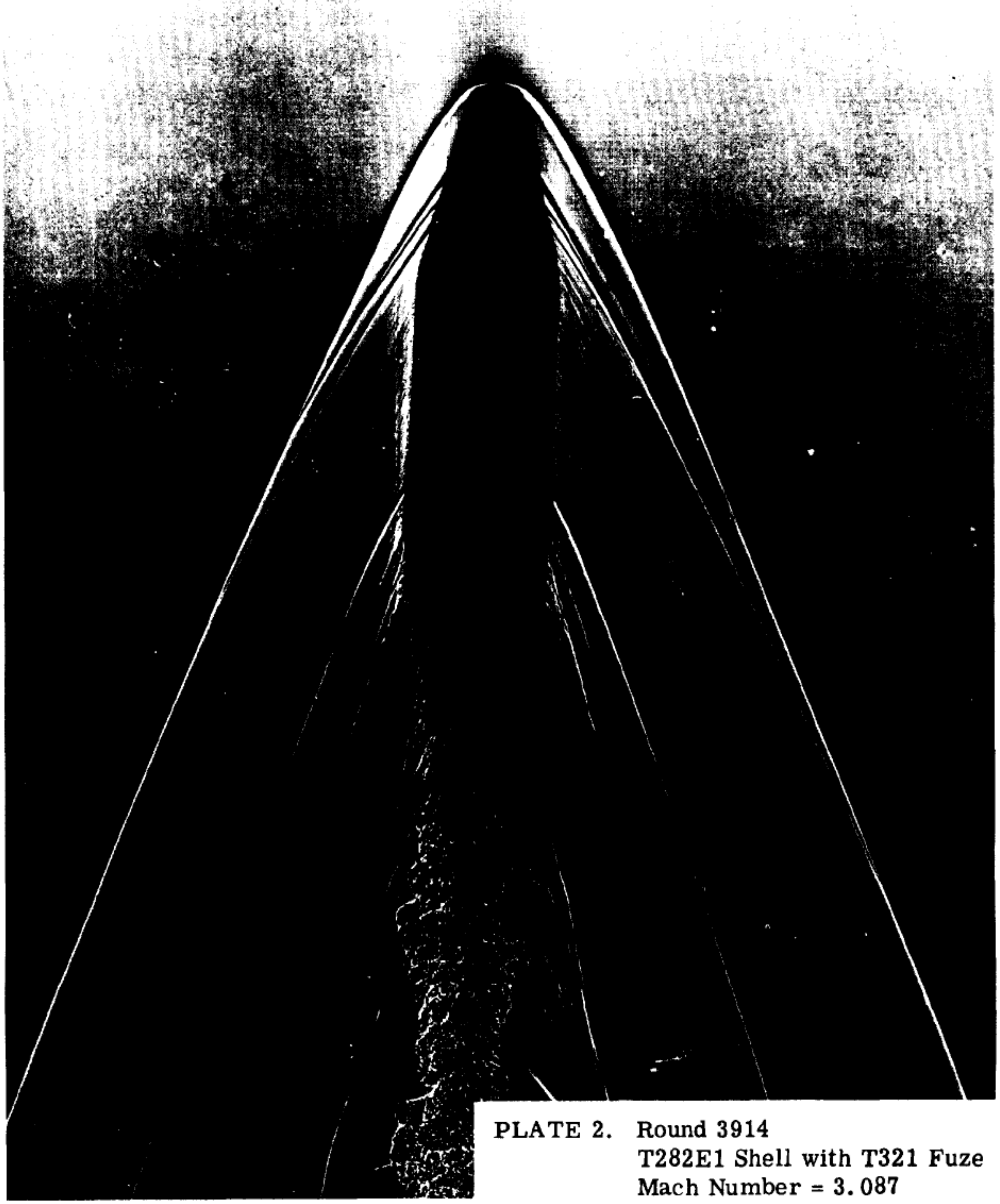

PLATE 2. Round 3914
T282E1 Shell with T321 Fuze
Mach Number = 3.087

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